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(54) **METHOD AND APPARATUS FOR SEALING FLEX CIRCUITS MADE WITH AN LCP SUBSTRATE**

VERFAHREN UND VORRICHTUNG ZUR VERSIEGELUNG VON MIT EINEM LCP-SUBSTRAT HERGESTELLTEN FLEX-SCHALTUNGEN

PROCEDE ET APPAREIL PERMETTANT DE SCELLER DES CIRCUITS IMPRIMES SOUPLES CONÇUS AU MOYEN D'UN SUBSTRAT LCP

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- **"AN OVERCOAT FOR PCBS" MACHINE DESIGN, PENTON MEDIA, CLEVELAND, OH, US, vol. 73, no. 10, 17 May 2001 (2001-05-17), page 116, XP001198851 ISSN: 0024-9114**

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EP 1 789 840 B1

Description

BACKGROUND OF THE INVENTION

[0001] Flexible or "flex" circuits are used in a wide variety of applications where an electrical circuit must bend around corners or be flexed during operation. Flex circuits are thin, light weight, flexible and exhibit high routability. Traditionally, polyimide films have been used as substrates in the manufacture of flex circuits due to their good thermal stability and mechanical strength. Other properties of polyimide films, however, limit the speed or frequency at which electric components mounted thereto can operate.

[0002] Liquid crystal polymer ("LCP") has been developed in recent years as a replacement for polyimide films in flex circuits. LCP is a thermoplastic aromatic polyester which is thermally stable, with an upper use temperature in excess of 250°C and good inherent flame retardant properties. LCP films, in comparison to polyimide films, have about one-tenth of the moisture uptake and a lower coefficient of humidity expansion. Lower moisture absorption leads to higher frequency signal and data processing. Additionally, LCP films have a lower dielectric constant and a lower loss or dissipation factor over the functional frequency range of 1kHz to 45 GHz, with negligible moisture effects, compared to polyimide films.

[0003] The fabrication of flex circuits with LCP films is expected to lead to their use in more demanding environments where moisture and other contaminants are prevalent. Particularly in such types of applications, the circuit elements applied to the LCP substrate of the flex circuit must be protected from damage. Soldermask coatings, which have been employed to provide protection from moisture and contaminants in polyimide films, have been considered for use with LCP substrates. Additionally, due to the thermoplastic nature of LCP, the application of an LCP film cover layer to an LCP substrate has been proposed as a means of effectively encapsulating circuit elements. For example, the magazine Machine Design published a respective article. According to this article, liquide-crystalline polymer films are intended for applications needing high operation temperatures. Additionally, it is described that the liquide-crystalline polymers are suitable for applications requiring high-density and high-frequency circuits. ("An overcoat for PCBs", Machine Design, Penton Media, Cleveland, OH, US; vol. 73, no 10, May 2001, page 116, ISSN 0024-9114). There is a need, however, for an efficient and dependable method and apparatus to perform such an encapsulation operation.

[0004] Document DE 199 20 577 C1 describes a membrane press for furniture plates. Substantially the membrane press consists of two membranes arranged to form a first and a second chamber and two reservoirs for warm and cold fluid. According to DE 199 20 577 C1, the membrane press operates as follows. Hot fluid is provided to the first chamber to coat the furniture plate with paper, leather or laminate. In a second step, pressurized air is provided to the second chamber. Due to the arrangement of the membranes, the pressurized air displaces the hot fluid in the first chamber. Hence, the hot fluid is removed from the first chamber. In a third step, an outlet of the second chamber is opened and additionally, the cold fluid is provided to the first chamber. In a fourth step, the outlet of the second chamber is closed and pressurized air is provided to empty the first chamber again. Finally, the press is opened and the coated furniture plate could be removed.

[0005] Document US 2,575,734 describes a press having a chamber formed by an elastic diaphragm and a press head. The elastic diaphragm is sealed to the press head. During a pressing operation, steam or hot water could be introduced into the chamber between the press head and the elastic diaphragm. Additionally, the chamber between the press head and the elastic diaphragm is connected to a source of cooling water. The flexible diaphragm is an elastomer such as rubber or a silicone polymer.

[0006] Document JP 2001 230528 A describes a device and a method to mount semiconductor elements on a printed circuit board. Therefore, IC chips are placed on a substrate. Diaphragms of elastic members are fitted to the side of the substrate on an upper die. This upper die is lowered and the diaphragm pressurizes the IC chips. Thus, the diaphragms are deformed along the shape of the substrate and the IC chip, and the substrate and the IC chips are pressurized uniformly as one.

SUMMARY OF THE INVENTION

[0007] This invention is directed to a method and apparatus for affixing an LCP cover layer to a flex circuit consisting of circuit elements mounted to an LCP substrate in order to protect the circuit elements from damage and/or reduced operational efficiency due to the presence of moisture and contaminants.

[0008] In the presently preferred embodiment, the apparatus includes an iso-static press having a hollow interior connected to a source of oil or other liquid whose temperature can be accurately controlled and maintained. The oil is heated to a temperature in the range of approximately 283°C to 320°C and transferred from a tank into the interior of the press. The base of the press has a plate or membrane formed of a flexible material covered with a non-stick surface which does not adhere to LCP.

[0009] The flex circuit is placed on a support such that the circuit elements are exposed. An LCP cover layer is then placed atop the flex circuit, after which time the press is activated to move into contact with the cover layer. The flexible membrane at the base of the press is capable of substantially conforming to the shape of the circuit elements, thus urging the LCP cover layer around them to the underlying LCP substrate of the flex circuit. The temperature and pressure applied by the press is sufficient

to cause the LCP cover layer and substrate to "flow" or melt to a limited extent and thus adhere together forming a secure bond so that the circuit elements between the two are substantially encapsulated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The structure, operation and advantages of the presently preferred embodiment of this invention will become further apparent upon consideration of the following description, taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a schematic, perspective view of the apparatus of this invention; and
FIG. 2 is a block diagram illustrating the operation of the apparatus shown in Fig. 1.

DETAILED DESCRIPTION OF THE INVENTION

[0011] Referring now to the Figs., the apparatus 10 of this invention is schematically illustrated. The apparatus 10 includes an iso-static press 12 having a housing 14 formed with a hollow interior. The base of the housing 14 mounts a flexible membrane 16 having an exposed surface coated with Teflon® or other release agent which will not stick to LCP, and an inside surface coated with a hydrophobic film. Preferably, the flexible membrane 16 is formed of high density polyethylene, butyl rubber, ethylene propylene diene monomer rubber or a similar material.

[0012] As discussed in more detail below, the press 12 is operative to apply heat and pressure against a cover layer 18 which overlies a flex circuit 20 placed upon a support 22. In the presently preferred embodiment, the press 12 is heated by the introduction into its hollow interior of heated oil or a similar fluid whose temperature can be relatively accurately controlled and maintained within the range of about 283°C to 325°C. A first reservoir 24 having heating elements (not shown) containing a valve 32, is connected by a supply line 26 to a manifold 28. A pump 30 and valve 32 are located in the supply line 26, between the first reservoir 24 and manifold 28, as shown. The manifold 28, in turn, is connected by an input line 34 to one port at the top of the press 12, and by an output line 38 to a second port. A recirculation line 42, containing a valve 32, is connected between the manifold 28 and the top of the first reservoir 24.

[0013] In view of the relatively high temperature obtained by the press 12 during operation, it is advantageous to provide a cooling capability to step the temperature down. To that end, a second reservoir 44 is provided which contains the same fluid as first reservoir 24 except at ambient temperature. The bottom of second reservoir 44 is connected by a line 46 to the manifold 28, and a recirculation line 48 connects the manifold 28 to the top of the second reservoir 44. A pump 30 and valve 32 are located in the line 46 between the second reservoir 44 and manifold 28, and a valve 32 is mounted in the recirculation line 48.

[0014] The press 12 is moved with respect to the support 22 by a number of pneumatic or hydraulic pistons 50 which are mounted at equal intervals along the top surface of the press 12. Conventionally, the pistons 50 are independently actuated by a source of air or fluid (not shown) to ensure that the press 12 applies uniform pressure to the cover layer 18 and flex circuit 20 over the entire surface area of the flexible membrane 16. The detailed construction of the press 12 forms no part of this invention, and is therefore not discussed further herein.

System Operation

[0015] As discussed above, the method and apparatus 10 of this invention are designed to provide a means for encapsulating circuit elements to protect them from moisture and contaminants. The flex circuit 20 consists of a substrate 52 formed of LCP upon which a number of circuit elements 54 are mounted. The cover layer 18 is also formed of LCP, which, because of its thermoplastic nature, will "flow" or begin to melt at a temperature of about 283°C. By placing the cover layer 18 over the flex circuit 20 and applying heat and pressure, the cover layer 18 and substrate 52 adhere to one another with a secure bond and entirely enclose the circuit elements 54 between them.

[0016] The apparatus 10 is operated by a commercially available controller 56 as schematically depicted in the flow diagram of Fig. 2. Initially, oil or other fluid within the first reservoir 24 is brought up to a temperature in the range of 283°C to 325°C by activating heating elements (not shown) therein. The controller 56 is operative to activate the heating elements via a signal input through lead 58, or they may be independently activated by a switch (not shown) located at the first reservoir 24. The controller 56 then inputs signals through leads 60 and 62 to start the pump 30 and open valve 32, respectively, thus initiating the flow of heated oil out of the first reservoir 24. When it is desired to heat the press 12 in preparation for circuit encapsulation, the controller 56 deactivates the pump 30 and valve 32 in line 46 from second reservoir 44 by signals input through leads 64 and 66, respectively. The heated oil flows into the press 12 through the manifold 28 and into the input line 34 leading into the interior of the press 12. Preferably, the temperature of the heated oil within the press 12 is controlled and maintained by continuously recirculating it from the first reservoir 24 through the manifold 28 and input line 34 into the press 12, and then out of the press 12 through the output line 38 and manifold 28 to the recirculation line 42 connecting the manifold 28 to the first reservoir 24. The controller 56 opens the valve 32 within recirculation line 42 via a signal input through line 68 to allow the heated oil to pass from the manifold 28 into the first reservoir 24.

[0017] With the press 12 at the appropriate temperature, the encapsulation process can proceed. The flex

circuit 16 is positioned on the support 22 so that the circuit elements 54 on the LCP substrate 52 are exposed. The LCP cover layer 18 is then placed atop the substrate 52 and circuit elements 54. The controller 56 operates the pistons 50 causing the press 12 to move toward the support 22. Upon engagement of the flexible membrane 16 at the bottom of the press 12 with the cover layer 18, at a uniform pressure on the order of 200 psi, the flexible plate 16 substantially conforms to the shape of the circuit elements 54 beneath. In turn, the cover layer 18 is forced around the circuit elements 54 into contact with substrate 52. The press 12 is maintained in this position for a period of time sufficient to heat both the LCP cover layer 18 and LCP substrate 52 to a melt temperature of at least 283°C, but not more than about 320°C, causing them to bond to one another and thus encapsulate the circuit elements 54 between the two.

[0018] After completing one or more encapsulation procedures, the temperature of the press 12 may be stepped down by circulating comparatively cool, ambient temperature oil into the press 12 from the second reservoir 44. The controller 56 is operative to deactivate the pump 30 and close valve 32 within line 26 connected to the first reservoir 24, while activating pump 30 and opening valve 32 within the line 46 connected to the second reservoir 44. The controller 56 closes the valve 32 within the recirculation line 42, and then opens the valve 32 within the recirculation line 48 extending from the manifold 28 to the second reservoir 44 by inputting a signal to such valve 32 through a line 70. As a result, ambient temperature oil is recirculated within the press 12 to reduce its temperature.

Claims

1. Apparatus (10) for sealing circuit elements of an electrical circuit between a substrate (20) upon which the circuit elements are mounted and a cover sheet (18) overlying the substrate (20) and circuit elements, each of the substrate (20) and cover sheet (18) being formed of liquid crystal polymer, said apparatus (10) comprising:

   an iso-static press (12) having a hollow interior, said hollow interior being connected to a first source (24) of heated fluid and a second source (44) of cooling fluid;
   a flexible membrane (16) mounted to said iso-static press (12) in position to contact the cover sheet (18); and
   a support (22) for carrying the substrate (20) and cover sheet (18);
   whereby said iso-static press (12) and flexible membrane (16) are adapted for exerting sufficient force and heat to cause the liquid crystal polymer forming both the cover sheet (18) and the substrate (20) to adhere together thus sealing the circuit elements between the two,
   characterised in that said iso-static press (12) is adapted for being at least partially filled with heating fluid when said iso-static press (12) is directed toward said support (22) so that said iso-static press (12) has been heated to an appropriate temperature before said flexible membrane (16) contacts said cover sheet (18) and substantially conforms to the shape of the circuit elements on the substrate (20).

2. The apparatus (10) of claim 1 in which said flexible membrane (16) is formed of a material chosen from the group consisting of high density polyethylene, butyl rubber and ethylene propylene diene monomer rubber.

3. The apparatus (10) of claim 1 in which said flexible membrane (16) is formed with a non-stick surface for contact with the cover sheet.

4. Method of sealing circuit elements of an electrical circuit between a substrate (20) upon which the circuit elements are mounted and a cover sheet (18) overlying the substrate (20) and circuit elements, each of the substrate (20) and cover sheet (18) being formed of liquid crystal polymer, said method comprises the following steps:

   placing said substrate (20) upon which the circuit elements are mounted on a support (22);
   placing said cover sheet (18) atop of said substrate (20) upon which the circuit elements are mounted;
   filling a hollow interior of said iso-static press (12) at least partially with heating fluid so that said iso-static press has been heated to an appropriate temperature before said iso-static press is directed towards said support (22);
   directing a iso-static press (12) towards said support (22) so that a flexible membrane (16), which is mounted to said iso-static press (12) in position to contact said cover sheet (18), contacts said cover sheet (18) and substantially conforms to the shape of the circuit elements on the substrate (20);
   exerting sufficient force and heat with said iso-static press (12) and said flexible membrane (16) to cause said liquid crystal polymer to adhere together thus sealing said circuit elements between said substrate (20) and said cover sheet (18).

5. The method of claim 4, wherein the temperature of said iso-static press (12) is stepped down by circulating a cooling fluid into said press from a second reservoir (44) after completing one or more sealing procedures.

6. The method of claim 4 or 5, wherein the temperature of the heating fluid provided to said iso-static press (12) is within a temperature range of 283°C to 325°C.

Patentansprüche

1. Vorrichtung (10) zum Abdichten von Schaltungselementen einer elektrischen Schaltung zwischen einem Substrat (20), auf dem die Schaltungselemente befestigt sind, und einer Abdeckplatte (18), die über dem Substrat (20) und den Schaltungselementen liegt, wobei das Substrat (20) und die Abdeckplatte (18) jeweils aus Flüssigkristallpolymer gebildet sind, wobei die Vorrichtung (10) umfasst:

   - eine Isostatpresse (12) mit einem hohlen Innenraum, wobei der hohle Innenraum mit einer ersten Quelle (24) für Heizfluid und einer zweiten Quelle (44) für Kühlfluid verbunden ist,
   - eine flexible Membran (16), die an der Isostatpresse (12) in Stellung zum Kontakt mit der Abdeckplatte (18) befestigt ist, und
   - eine Trageinrichtung (22) zum Tragen des Substrats (20) und der Abdeckplatte (18),
   - wodurch die Isostatpresse (12) und die flexible Membran (16) dazu geeignet sind, ausreichend Kraft und Wärme anzuwenden, um zu bewirken, dass das Flüssigkristallpolymer, das sowohl die Abdeckplatte (18) als auch das Substrat (20) bildet, zusammenklebt und somit die Schaltungselemente zwischen den beiden abdichtet,
   - **dadurch gekennzeichnet, dass** die Isostatpresse (12) dazu geeignet ist, zumindest teilweise mit Heizfluid gefüllt zu sein, wenn die Isostatpresse (12) zur Trageinrichtung (22) geführt wird, so dass die Isostatpresse (12) auf eine geeignete Temperatur erwärmt wird, bevor die flexible Membran (16) die Abdeckplatte (18) berührt und sich im Wesentlichen an die Form der auf dem Substrat (20) befindlichen Schaltungselemente anpasst.

2. Vorrichtung (10) nach Anspruch 1, wobei die flexible Membran (16) aus einem Material gebildet ist, das aus der Gruppe ausgewählt wird, die aus hochdichtem Polyethylen, Butylkautschuk und Ethylenpropylendienmonomerkautschuk besteht.

3. Vorrichtung (10) nach Anspruch 1, wobei die flexible Membran (16) mit einer nichthaftenden Oberfläche zum Kontakt mit der Abdeckplatte ausgebildet ist.

4. Verfahren zum Abdichten von Schaltungselementen einer elektrischen Schaltung zwischen einem Substrat (20), auf dem die Schaltungselemente befestigt sind, und einer Abdeckplatte (18), die über dem Substrat (20) und den Schaltungselementen liegt, wobei das Substrat (20) und die Abdeckplatte (18) jeweils aus Flüssigkristallpolymer gebildet sind, wobei das Verfahren die folgenden Schritte umfasst:

   - Platzieren des Substrats (20), auf dem die Schaltungselemente befestigt sind, auf einer Trageinrichtung (22),
   - Platzieren der Abdeckplatte (18) über dem Substrat (20), auf dem die Schaltungselemente befestigt sind,
   - Füllen eines hohlen Innenraums der Isostatpresse (12) zumindest teilweise mit Heizfluid, so dass die Isostatpresse auf eine geeignete Temperatur erwärmt wird, bevor die Isostatpresse zur Trageinrichtung (22) geführt wird,
   - Führen einer Isostatpresse (12) zur Trageinrichtung (22), so dass eine flexible Membran (16), die an der Isostatpresse (12) in Stellung zum Kontakt mit der Abdeckplatte (18) befestigt ist, die Abdeckplatte (18) berührt und sich im Wesentlichen an die Form der auf dem Substrat (20) befindlichen Schaltungselemente anpasst,
   - Anwenden von ausreichend Kraft und Wärme durch die Isostatpresse (12) und die flexible Membran (16), um zu bewirken, dass das Flüssigkristallpolymer zusammenklebt und somit die Schaltungselemente zwischen dem Substrat (20) und der Abdeckplatte (18) abdichtet.

5. Verfahren nach Anspruch 4, wobei die Temperatur der Isostatpresse (12) nach Abschluss eines oder mehrerer Abdichtvorgänge durch Zirkulieren eines Kühlfluids von einem zweiten Reservoir (44) in die Presse stufenweise gesenkt wird.

6. Verfahren nach Anspruch 4 oder 5, wobei die Temperatur des der Isostatpresse (12) zugeführten Heizfluids innerhalb eines Temperaturbereichs von 283°C bis 325°C liegt.

Revendications

1. Appareil (10) pour sceller des éléments de circuit d'un circuit électrique entre un substrat (20) sur lequel les éléments de circuit sont montés et une feuille de recouvrement (18) recouvrant le substrat (20) et les éléments de circuit, chacun du substrat (20) et de la feuille de recouvrement (18) étant constitué(e) d'un polymère à cristaux liquides, ledit appareil (10) comprenant :

   une presse isostatique (12) ayant un intérieur creux, ledit intérieur creux étant connecté à une première source (24) de fluide chauffé et une deuxième source (44) de fluide de refroidissement ;
   une membrane flexible (16) montée sur ladite

presse isostatique (12) en position pour être en contact avec la feuille de recouvrement (18) ; et un support (22) pour supporter le substrat (20) et la feuille de recouvrement (18) ;
d'où il résulte que lesdites presse isostatique (12) et membrane flexible (16) sont adaptées à exercer une force et une chaleur suffisantes pour faire en sorte que les polymères à cristaux liquides formant à la fois la feuille de recouvrement (18) et le substrat (20) adhèrent ensemble, scellant ainsi les éléments de circuit entre les deux,
caractérisé en ce que ladite presse isostatique (12) est adaptée à être au moins partiellement remplie avec un fluide de chauffage lorsque ladite presse isostatique (12) est dirigée vers ledit support (22), de sorte que ladite presse isostatique (12) a été chauffée à une température appropriée avant que ladite membrane flexible (16) ne vienne en contact avec ladite feuille de recouvrement (18) et se conforme sensiblement à la forme des éléments de circuit sur le substrat (20).

2. Appareil (10) selon la revendication 1, dans lequel ladite membrane flexible (16) est constituée d'un matériau choisi parmi le groupe consistant en un polyéthylène haute densité, un caoutchouc butylique et un caoutchouc de monomères éthylène-propylène-diène.

3. Appareil (10) selon la revendication 1, dans lequel ladite membrane flexible (16) est formée avec une surface non adhésive pour un contact avec la feuille de recouvrement.

4. Procédé pour sceller des éléments de circuit d'un circuit électrique entre un substrat (20) sur lequel les éléments de circuit sont montés et une feuille de recouvrement (18) recouvrant le substrat (20) et les éléments de circuit, chacun du substrat (20) et de la feuille de recouvrement (18) étant constitué(e) d'un polymère à cristaux liquides, ledit procédé comprenant les étapes suivantes :

mise en place dudit substrat (20) sur lequel les éléments de circuit sont montés sur un support (22) ;
mise en place de ladite feuille de recouvrement (18) par-dessus ledit substrat (20) sur lequel les éléments de circuit sont montés :

remplissage d'un intérieur creux de ladite presse isostatique (12) au moins partiellement avec un fluide de chauffage de sorte que ladite presse isostatique a été chauffée à une température appropriée avant que ladite presse isostatique ne soit dirigée vers ledit support (22) ;
avancée d'une presse isostatique (12) vers ledit support (22) de sorte qu'une membrane flexible (16) qui est montée sur ladite presse isostatique (12) en position pour être en contact avec ladite feuille de recouvrement (18), est en contact avec ladite feuille de recouvrement (18) et se conforme sensiblement à la forme des éléments de circuit sur le substrat (20) ;
exercice d'une force et d'une chaleur suffisantes avec ladite presse isostatique (12) et ladite membrane flexible (16) pour faire en sorte que lesdits polymères à cristaux liquides adhèrent ensemble, scellant ainsi lesdits éléments de circuit entre ledit substrat (20) et ladite feuille de recouvrement (18).

5. Procédé selon la revendication 4, dans lequel la température de ladite presse isostatique (12) est abaissée par pas en faisant circuler un fluide de refroidissement dans ladite presse à partir d'un deuxième réservoir (44) après la fin d'une ou plusieurs procédure(s) de scellage.

6. Procédé selon la revendication 4 ou 5, dans lequel la température du fluide de chauffage prévu dans ladite presse isostatique (12) est à l'intérieur d'une plage de température de 283 °C à 325 °C.

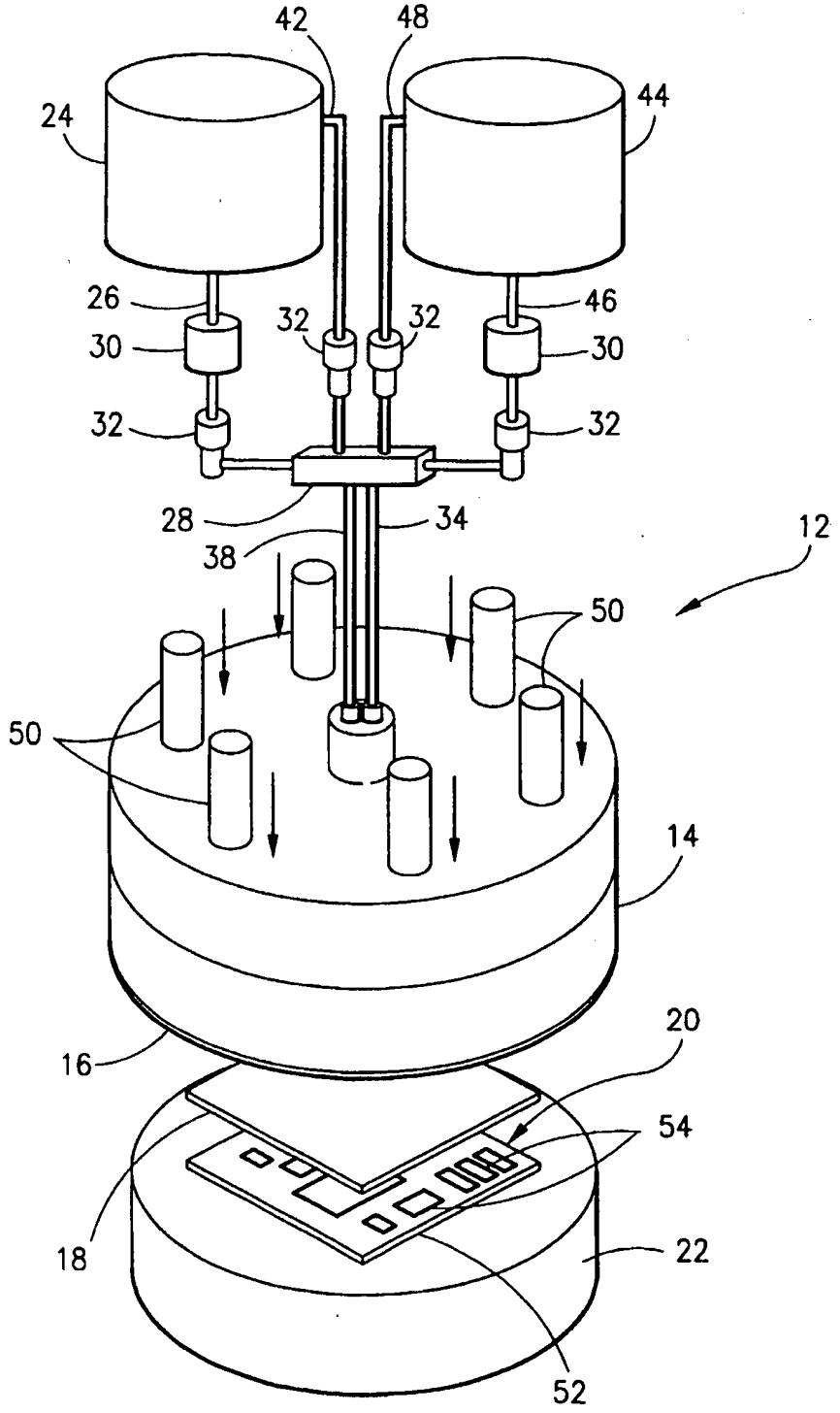
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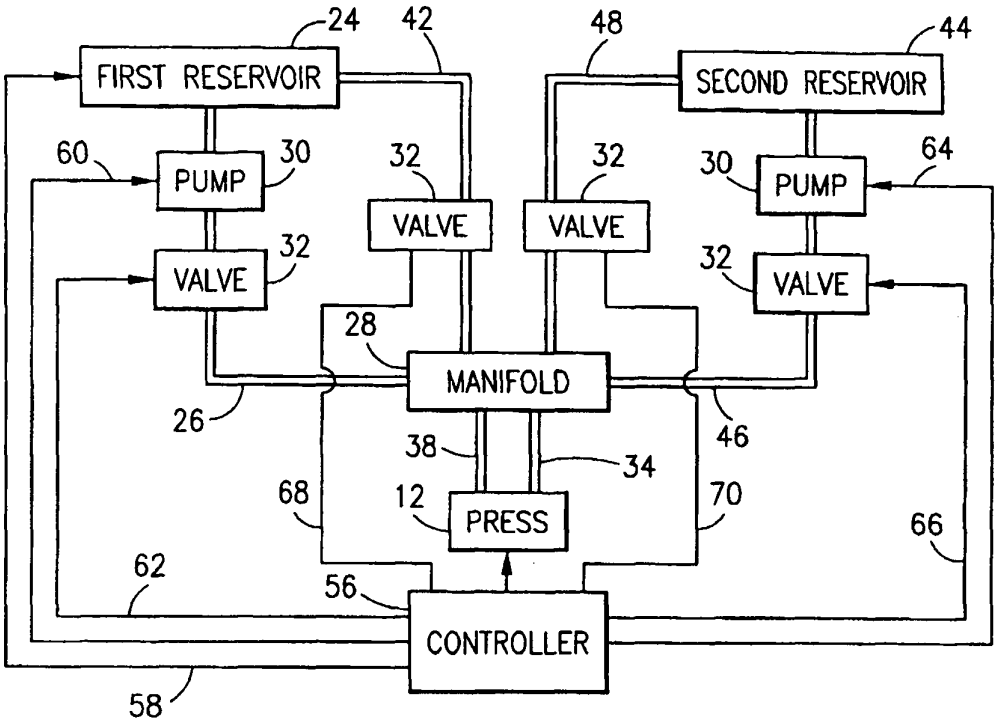
FIG. 1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FIRST RESERVOIR
SECOND RESERVOIR
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PUMP
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VALVE
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VALVE
28
MANIFOLD
26
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34
68
12
PRESS
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CONTROLLER
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FIG. 2

REFERENCES CITED IN THE DESCRIPTION

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- US 2575734 A **[0005]**
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